RESEARCH REPORT

CASE STUDIES OF POTENTIAL APPLICATIONS OF INNOVATIVE RESIDENTIAL WATER AND WASTEWATER TECHNOLOGIES

EXTERNAL RESEARCH PROGRAM

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CASE STUDIES OF POTENTIAL APPLICATIONS OF INNOVATIVE RESIDENTIAL WATER AND WASTEWATER TECHNOLOGIES

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Report to

Research Division
Canada Mortgage and Housing Corporation

January, 1999

Project Officer
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CASE STUDIES OF POTENTIAL APPLICATIONS OF INNOVATIVE RESIDENTIAL WATER AND WASTEWATER TECHNOLOGIES

Abstract

Objectives of this project were to identify and describe opportunities for use of innovative water supply and wastewater systems for residential buildings, to compare costs and benefits of traditional and innovative systems, and to propose solutions that could lead to more cost-effective and environmentally friendly housing. The innovative technologies considered are those used in the Toronto Healthy House: a rainwater cistern system, and recycling of all household wastewater for non-potable uses. In five case study sites in Nova Scotia, life cycle costs of these technologies were compared with costs of traditional infrastructure alternatives —municipal water and wastewater, or wells and on-site sewage disposal systems. These comparisons indicate that the Healthy House technologies could be cost-competitive in an urban or suburban subdivision if fire protection is not required; a non-urban area as an alternative to a cluster system, or in a non-urban area as an alternative to a remedial central system. Other situations where they might be appropriate are also discussed. Other, non-cost, issues—technological, management, regulatory, and public and political—that must be considered if these technologies are to be adopted are identified and discussed. Recommendations are offered about strategies and actions that can take advantage of opportunities and address problems and issues related to adoption of innovative technologies for residential water supply and wastewater management.

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- Robert Anderson, Nova Scotia Department of the Environment
- Alan Brady, Halifax Regional Municipality
- Reid Campbell, Halifax Regional Water Commission
- Hubert Fougere, Nova Scotia Department of Housing and Municipal Affairs
- Andre Robichaud, CMHC, Atlantic Region.

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1. INTRODUCTION

1.1 Project Objectives

The objectives of this project were:

- to identify and describe opportunities for use of innovative systems for water supply, water conservation, wastewater recycling and reuse, and rainwater cistern systems in residential buildings
- to compare—for traditional and innovative systems—real and intangible costs and benefits
- to identify and describe institutional and technological barriers to adoption of innovative systems
- to propose solutions that could lead to adoption of innovative systems as a basis for more cost-effective and environmentally friendly residential housing developments.

1.2 Project Scope

The study was to be based on three case study situations:

- a new urban development serviced by central water and wastewater systems
- a new non-urban development with on-site services
- an existing non-urban area where new wells, new on-site systems, and a cluster system, are proposed to replace failing on-site systems and contaminated wells.

Information obtained during the project provided the opportunity to add two more case study situations:

- a new non-urban development served with public water and on-site wastewater systems
- a community where a central sewerage system has been proposed to replace failing on-site systems.

In each case the project compared traditional servicing alternatives with all or part of the alternative technologies that are incorporated in the Toronto Healthy House (1): water conservation, wastewater recycling and reuse, and a rainwater cistern system.

The case studies were drawn from Nova Scotia, but conclusions based on the results of this study were to be applicable to other areas of Canada.

2. METHODOLOGY

This project benefited from two specific sources of information and advice:

- the Project Advisory Committee, which included representatives of the
  - Nova Scotia Department of the Environment
  - Nova Scotia Department of Housing and Municipal Affairs
  - Halifax Regional Municipality
  - Halifax Regional Water Commission
  - the regional office of Canada Mortgage and Housing Corporation (CMHC).
- a concurrent project conducted for CMHC, which provides a detailed assessment of innovations in residential water and wastewater management.

The five case study sites, and related information sources, were identified with the assistance of the Advisory Committee.

Based on available information, each site was described in terms of demographics, servicing, and servicing costs associated with actual or proposed developments.

For each development, the WATERSAVE program (2), developed for CMHC by the Centre for water Resources Studies (CWRS), was used to describe the following scenarios for innovative water and wastewater management:

- water conservation
- water conservation plus greywater reuse for flushing and irrigation
- water conservation plus greywater and blackwater recycling for all except potable uses based on an average residence in each development.

Conventional and innovative systems were compared in terms of dollar costs and intangible costs and benefits.

Examples of the application of innovative technologies, and potential situations where these technologies might be applied, were identified and described, drawing heavily on results of parallel projects that were conducted for CMHC (3)(4).

Strategies and actions that might be adopted to produce more cost-effective application of innovative residential technologies were identified and described.

3. CASE STUDY SITES

3.1 Introduction

3.1.1 General

Four of the sites considered here are located within the Halifax Regional Municipality (Figure 3.1):

1) *Millwood* is a subdivision, developed in 1995-1996, that is served by municipal water, and sanitary and storm sewers.
2) *Kingswood* is a suburban subdivision, developed in 1996-1998, that is served by municipal water and on-site wastewater systems.
3) *Glen Arbour* is a suburban subdivision, developed in 1996-1998, that is served by wells and on-site water and wastewater systems.
4) *Harrietsfield and Williamswood,* areas where re-servicing has been proposed because of failing on-site sewage disposal systems, were the subject of a consultant's report (5) in 1987.

The fifth site is located in Antigonish County in northern Nova Scotia:

5) *Pomquet* is a small community where failing on-site systems in one area have led to a proposal to install a central system.

Information about each of these systems is provided in Sections 3.2 to 3.6.

3.1.2 Cost Considerations

Capital, operating and maintenance costs for municipal and cluster systems include the cost of the complete water system – source, treatment, transmission, and local delivery, and the cost of the complete wastewater collection, transport, and treatment system. All costs are expressed in 1998 Canadian dollars. Cost projections assume a municipal borrowing rate of 6 percent.

Historical costs have been projected to 1998, and 1998 costs projected to the future, using a compounded annual rate of increase in the Engineering New Record (ENR) Construction Index (5), from its beginning in 1913 until 1998, of 4.8 percent. Values of the index over this period, when plotted against calculated values based on this rate, compare well.

Estimated costs per lot for municipal water service are based on data from the Halifax Regional Water Commission (HRWC). They include estimated 1998 costs for the complete source, treatment, transmission, and distribution system. The portion of these costs to deliver treated water to the Millwood and Kingswood subdivisions is approximately $2,500 per lot. The average cost of the local distribution system in Millwood, where lot frontages are 12 to 18 m, was $5,522. The local distribution system cost in Kingswood, with average frontage of about 46 m, was approximately $10,950 per lot. These costs include building services from street to house.

Information about off-site costs for sewage transmission and treatment systems was not available. It was assumed that the ratio of off-site to subdivision costs for Millwood was the same as for the municipal water system, i.e., 1.83. This ratio, applied to the average sanitary sewer cost, yielded a total estimated cost per lot of $7340.

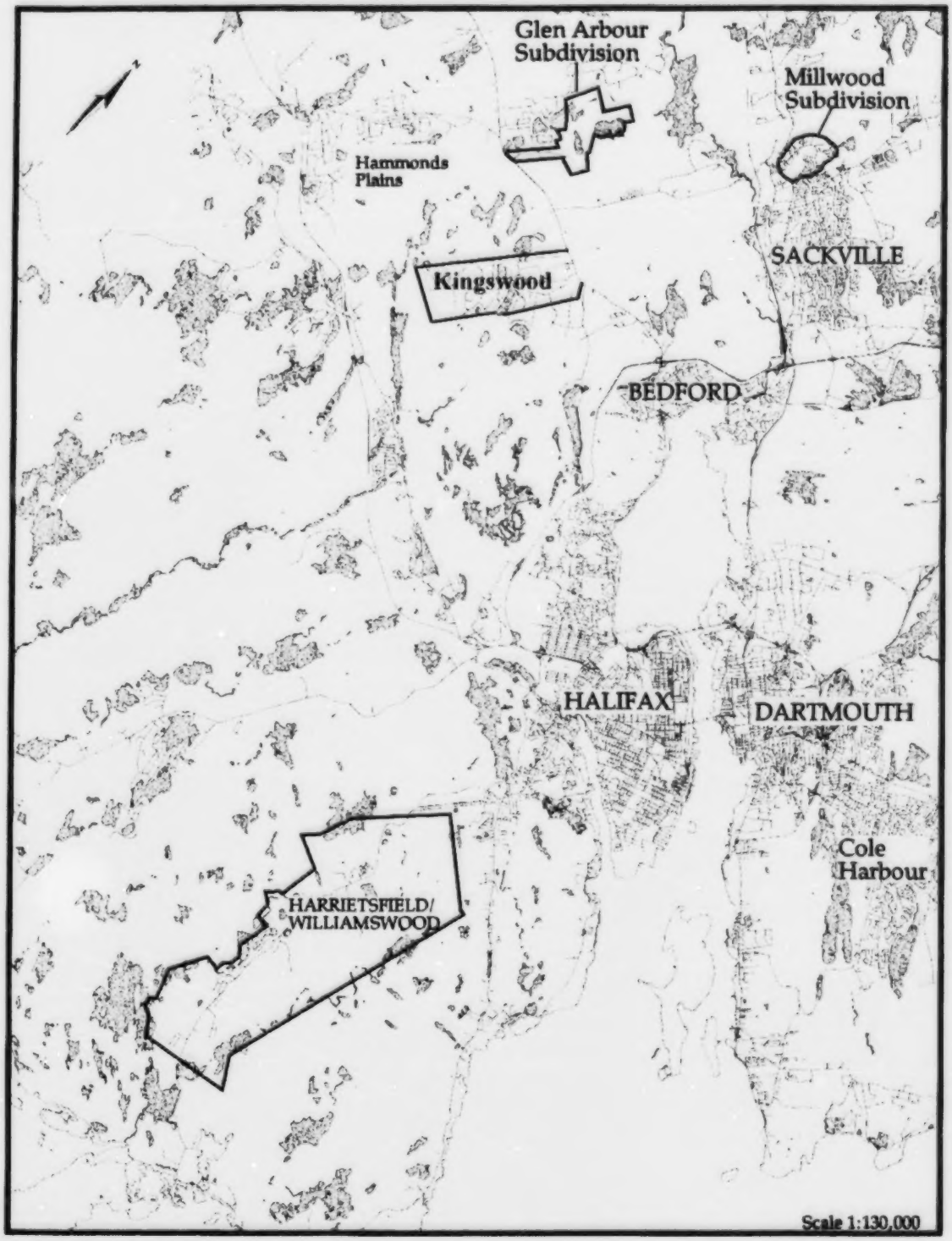


Figure 3.1 Locations of Case Study Sites

The following operation and maintenance costs (per lot per year) were used:

- HRWC system - $257
- sanitary sewerage system - $257
- private well, including power and service - $57
- on-site sewage system, including service and pumping at 3-year intervals - $104
- cluster system, taken from reference (7) and updated to 1998 - $89

3.2 Millwood

3.2.2 General

Millwood (Figure 3.2) is located 25 km north of the City of Halifax, within the community of Lower Sackville. Millwood is a new residential subdivision, developed and serviced by the Nova Scotia Department of Housing and Consumer Affairs. Individual lots were developed, and houses constructed, by private contractors.

3.2.2 Natural Conditions

Prior to development the site was heavily treed, and the topography consisted of gently rolling hills with a stream running through the centre of the site from northwest to southeast. The stream discharges to a marsh area prior to joining the Sackville River. There are no natural or artificial ponds or lakes in the Millwood site.

3.2.3 Developments

The total area to be developed is 142 ha. To the end of 1998, an area of 126 ha, which includes 900 housing lots, had been developed. The area remaining to be developed is 16 ha, which will include multi-family buildings. Figure 3.2 shows only the phases of the development on which the costs used here are based.

3.2.4 Servicing

Water mains and sanitary sewers are connected to systems operated by the Halifax Regional Municipality (HRM) and the Halifax Regional Water Commission (HRWC). Storm sewers drain to the stream passing through the subdivision, or to the HRM system that drains to the Sackville River.

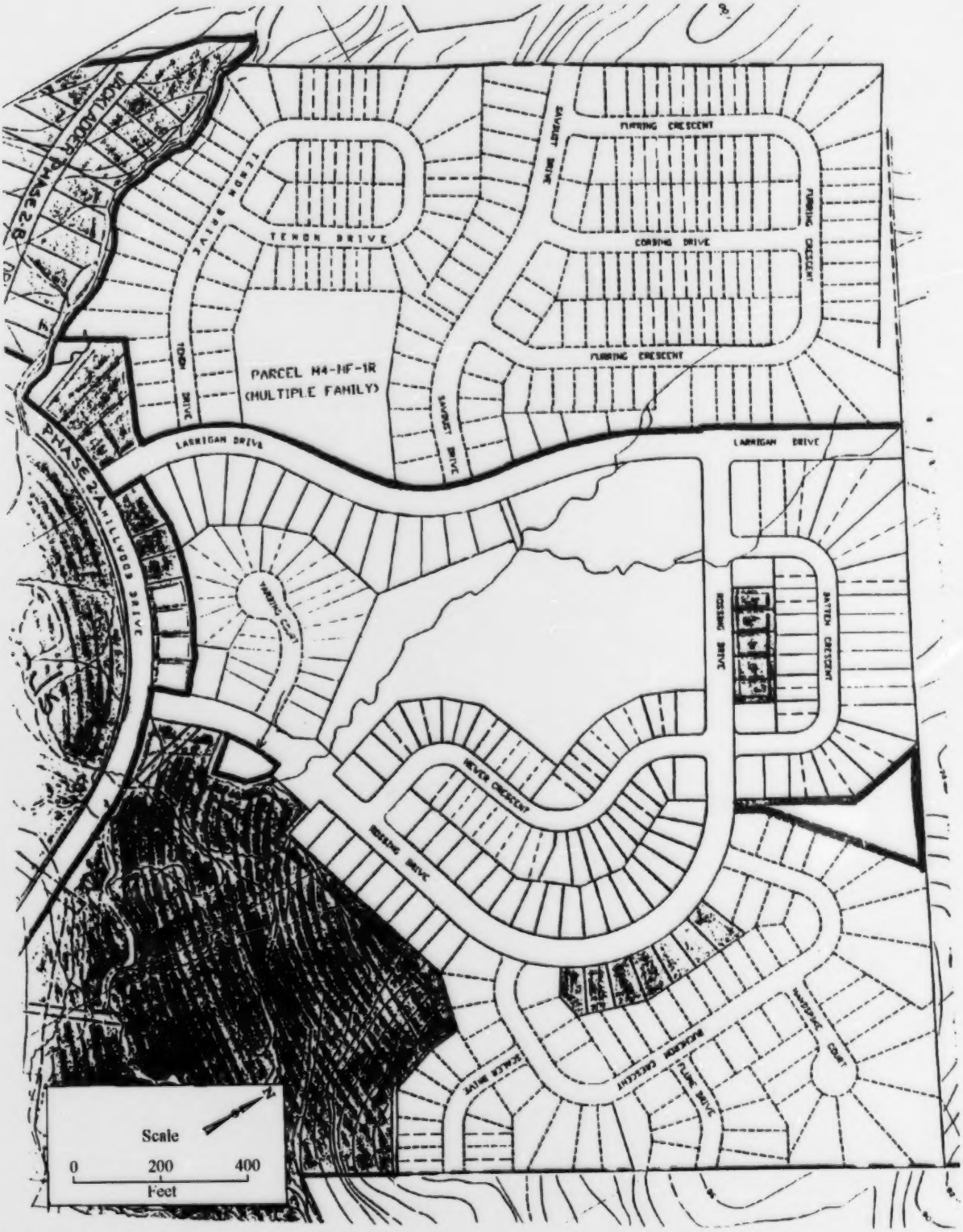


Figure 3.2 Millwood

Figure 3.2 Millwood

3.2.5 Servicing Costs

Information related to the cost of installing central services for the new Millwood subdivision was acquired from Nova Scotia Department of Housing and Consumer Affairs and the Halifax Regional Municipality. Information about the cost of private service connections, and the cost of internal plumbing, was acquired from private contractors in the region. Excavation in this subdivision did not encounter rock.

Table 3.1 shows costs for servicing an average 15 m wide lot in Millwood.

Millwood is the only one of the systems considered here that includes a piped stormwater system, which is included in a common trench with other services. If stormwater was provided in the absence of other services, the estimated extra cost to excavate a trench for stormwater alone would be $800 per lot.

Table 3.1
Servicing Costs for Single Family Lot in Millwood

Item	Average Cost Per Lot	
	Capital	Annual O&M
Sanitary Sewers	$7,341	$257
Water Supply	$5,522	$257
Plumbing	$5,000	
	$17,863	$514
Stormwater	$800	

3.3 Kingswood

3.3.1 General

Kingswood (Figure 3.3), located in the Halifax Regional Municipality, is a single family subdivision developed by the Armoyan Group of Halifax. Individual lots have been developed and serviced by individual contractors.

3.3.2 Natural Conditions

Prior to development the site was forested. It includes 3 small lakes and several ponds. Soils in the area are described as sandy loam, and the topography as gently undulating.

3.3.3 Developments

The total area of the subdivision is approximately 5000 ha. It includes about 1000 lots with an average area of 0.5 ha, plus parklands and a school site.

Figure 3.3 Kingswood

3.3.4 Servicing

The water distribution system is serviced by the Halifax Regional Water Commission. Wastewater disposal is provided by individual on-site systems. Stormwater is collected by roadway ditches and culverts.

3.3.5 Servicing Costs

Table 3.2 shows costs for servicing of an average 46 m wide lot in Kingswood.

Table 3.2
Servicing Costs for Single Family Lot in Kingswood

Item	Average Cost Per Lot	
	Capital	Annual O&M
On-site Sewage	$5,900	$104
Water Supply	$10,947	$257
Plumbing	$5,000	
	$21,847	$361

3.4 Glen Arbour

3.4.1 General

Glen Arbour (Figure 3.3) is an integrated golf course and residential community, developed by the Annapolis Basin Group Incorporated. Individual lots have been developed and serviced by private contractors.

3.4.2 Natural conditions

The site consisted of heavily forested gently rolling terrain. Three lakes, inter-connected by brooks, occupy part of the site. Available soil mapping indicates that soils are a sandy loam of the Halifax series, derived from quartzite parent material, stony, and good to excessively drained.

3.4.3 Developments

Two hundred single family units occupy 81 ha; future low-density multiple units will occupy 26 ha. The golf course occupies 75 ha of the site. Approximately half of the lake frontage is dedicated to residential lots, the remaining half to the golf course. Street rights-of-way occupy 12 ha.

Figure 3.4 Glen Arbour

3.4.4 Servicing

Water supply and sewage disposal is provided by on-site wells and septic tank disposal systems. Storm drainage is provided by roadway ditches and culverts. Water from the lakes on the site will be used for golf course irrigation.

3.4.5 Servicing Costs

Average servicing costs for a single family property in Glen Arbour are listed in Table 3.2. Based on local soil conditions the average on-site sewage disposal system required by Nova Scotia guidelines (8) would be a C2 contour system.

Table 3.3
Servicing Costs for Single Family Lot in Glen Arbour

Item	Average Cost Per Lot	
	Capital	**Annual O&M**
On-site Sewage	$4,500	$104
Well	$4,000	$57
Plumbing	$5,000	
	$13,500	$161

3.5 **Harrietsfield and Williamswood**

3.5.1 General

This site follows the Old Sambro Road from the City of Halifax limit to Sambro (Figure 3.4). This area is typically sparsely covered rock with swampy conditions in low-lying areas. There are over 10 lakes in the study area, which are generally shallow. The predominant physical feature in the region is a series of hills, or drumlins, that occur at intervals along the Old Sambro Road. There are 7 or 8 of these, upon which most of the developments exist.

The present Municipal Planning strategy describes the majority of the study area as being of a rural, residential nature. The exception to this is an area around the community of Harrietsfield, which is described as a commercial/industrial Village Centre. The remainder of the study area, outside Harrietsfield boundary, is Williamswood, which is considered a rural area. In 1987 the area included 320 houses, most of which were constructed between 1960 and 1980.

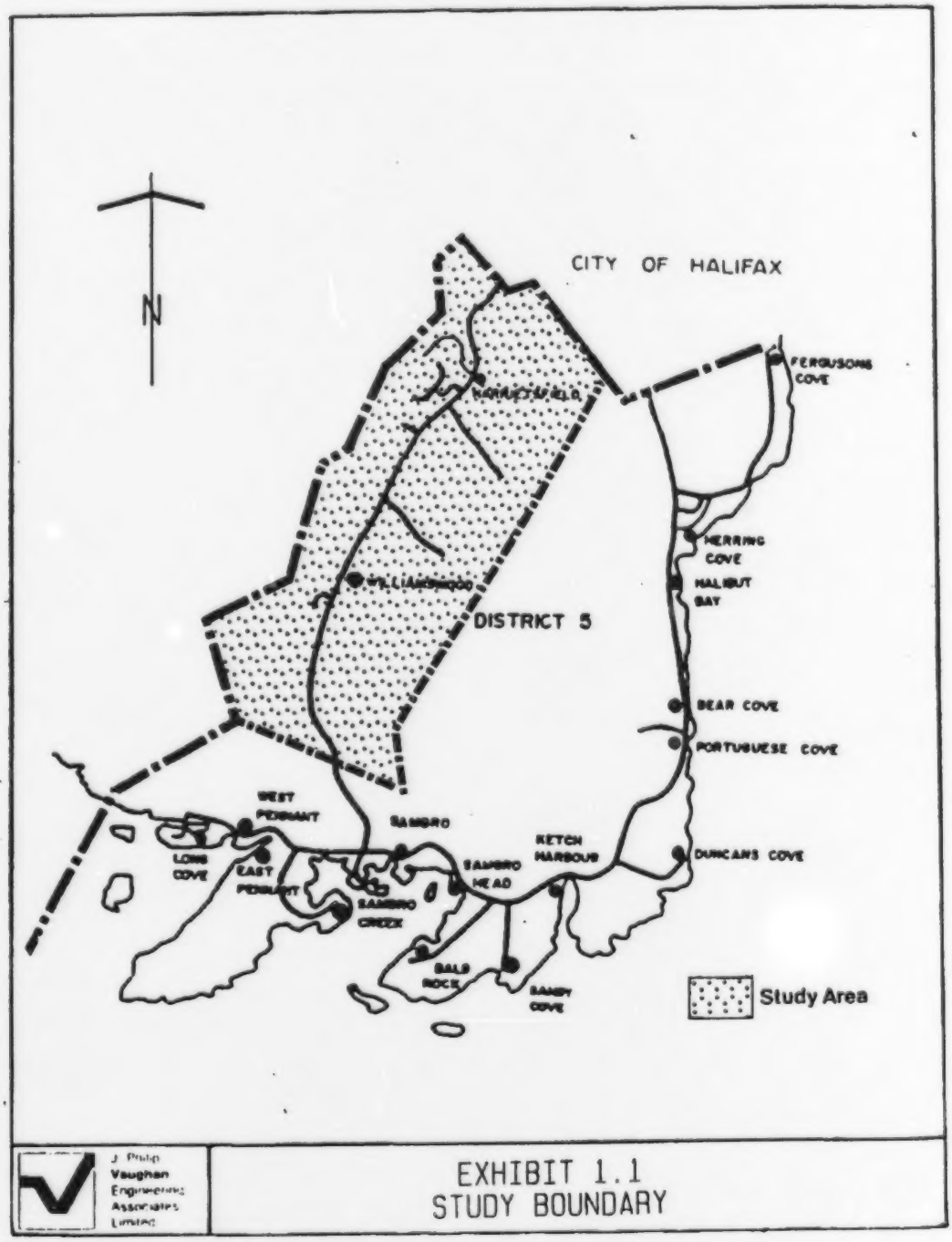


Figure 3.5 Harrietsfield/Williamswood

3.5.2 Servicing

The Harrietsfield/Williamswood area is presently serviced by private on-site wastewater disposal systems. These systems vary significantly in age and condition, and some do not function to proper public health standards. The water supply consists of privately owned drilled or dug wells. Sampling programs have identified potential concerns with drinking water quality in the study area.

A sanitary survey conducted by Nova Scotia Department of Health in 1983 indicated significant problems with the Harrietsfield/Williamswood on-site sewage disposal systems. Approximately 19 percent of on-site sewage disposal systems within the study area have been characterized as malfunctioning (6).

Up to 50 percent of the existing malfunctioning on-site sewage disposal systems can be repaired. Approximately 15 percent of individual wells in the study area were experiencing some form of bacteriological contamination or had elevated concentrations of naturally occurring uranium.

A 1987 consultant's report (6) recommended strategies to address health or environmental problems associated with malfunctioning on-site disposal systems and contaminated wells:

- repair or replacement of existing on-site systems
- cluster collection and disposal systems in two areas or subdivisions where malfunctions are common
- remedial work for 35 wells in the area, noting that 3% of the wells had uranium concentrations greater than the then-current drinking water limit of 0.02 mg/L (since raised to 0.1 mg/L), and others had elevated bacterial counts.

3.5.3 Servicing Costs

Table 3.4 summarizes estimated costs to address problems associated with malfunctioning on-site systems and contaminated wells. Included are: average costs to repair or replace 100 malfunctioning on-site systems; the average cost per lot for two cluster systems (sewers and sub-surface disposal systems) serving a total of 37 homes; cost to replace wells contaminated by bacteria; and the cost of alternative wells and/or treatment where uranium concentrations were high.

Table 3.4
Re-servicing Costs for Single Family Lots in Harrietsfield/Williamswood

Item	Average Cost Per Lot	
	Capital	Annual O&M
On-site Sewage	$4,690	$104
Cluster System	$14,800	$89
Well - bacteria	$3,828	$57
- uranium	$6,566	$57

3.6 **Pomquet**

3.6.1 General

Pomquet is a small community located along a highway in northern Nova Scotia (Figure 3.5). Most of the houses in this area were constructed prior to 1970. Failing on-site systems led to recommendations for installation of a new sanitary sewerage system and treatment plant, which would serve 32 existing lots and 18 future lots (9).

3.6.2 Natural Conditions

Lot sizes and soil conditions are apparently not suitable for repair or replacement of failing on-site systems.

3.6.3 Developments

The proposed system will provide wastewater services to the existing 32 lots, plus a church and small college. Future in-fill is expected to add 18 more lots to the system.

3.6.4 Servicing

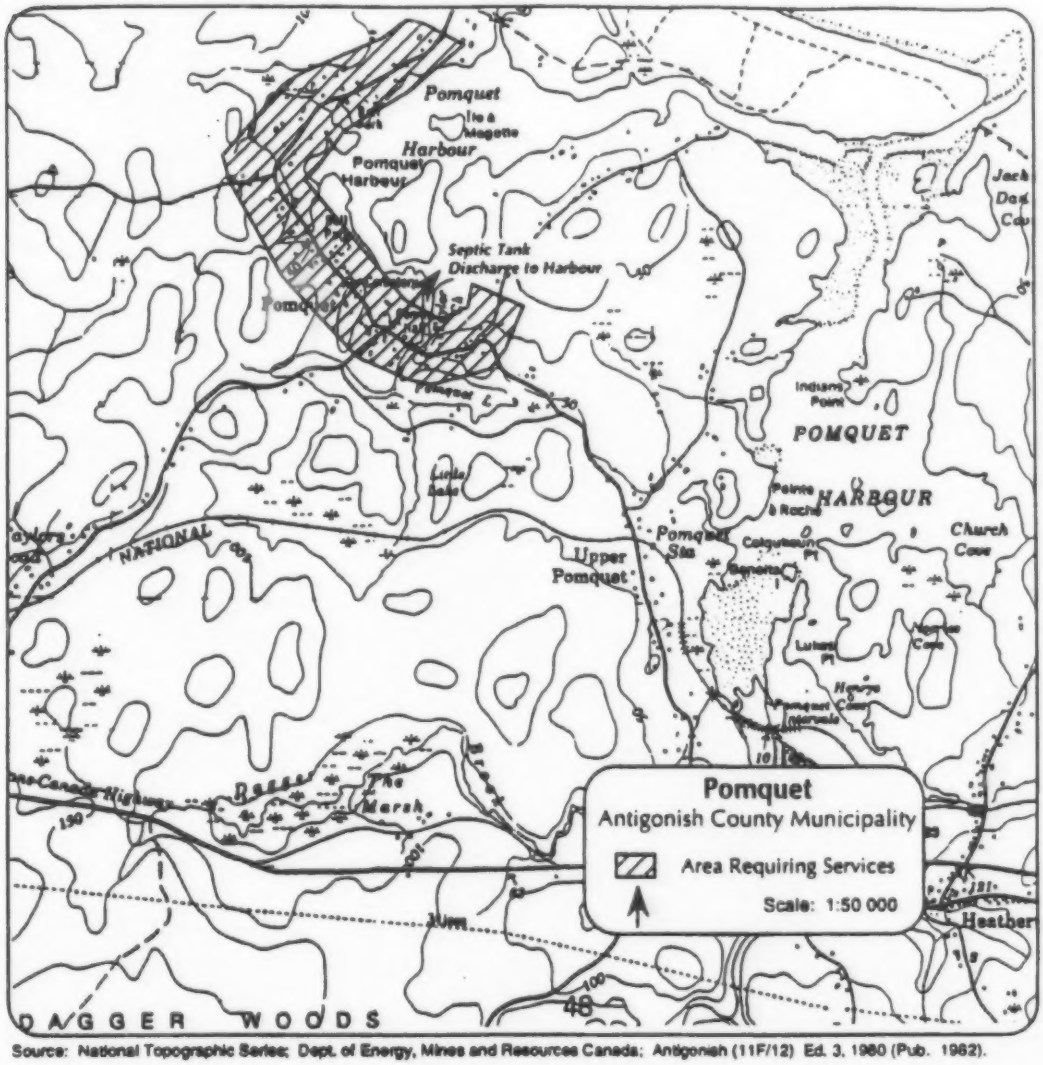
No problems are reported with the individual wells that service this area. Storm drainage is provided by ditches and culverts. The proposed gravity sewerage system for 50 lots would also require 3 pumping stations, and treatment would be provided by a sequencing batch reactor and sand filtration before discharge to Pomquet Harbour.

3.6.5 Servicing Costs

Table 3.5 shows estimated costs to provide remedial wastewater services to Pomquet. The estimate recognizes that the municipality will incur interest costs for the 18 unused services, and assumes that these costs will be recovered over 20 years.

Table 3.5
Re-servicing Costs for Single Family Lot in Pomquet

Item	Average Cost Per Lot	
	Capital	Annual O&M
Public Sewer System	$18,000	$257
Carrying Charges	$2,000	$57
	$20,000	$314



Source: National Topographic Series; Dept. of Energy, Mines and Resources Canada; Antigonish (11F/12) Ed. 3, 1980 (Pub. 1982).

NOTES: *Poor soil, small lots, obvious malfunctions*
Cost of servicing about equal to assessed value.

Figure 3.6 Pomquet

4. INNOVATIVE SYSTEMS

4.1 System Characteristics

The water supply and wastewater renovation and disposal systems considered here are those used in the Toronto Healthy House, and more recent systems installed or proposed for other locations in Canada that are based on the THH technology.

4.1.1 Flows

It was assumed, as a basis for the comparisons in this report, that the average dwelling in each of the 5 developments is a 4-person single-family residence. Flows in conventional and innovative systems, with and without water conservation, are illustrated in Figure 4.1.

The source of potable water in the Healthy House system, which is supplied to kitchen and bathroom sinks, is a rainwater cistern system (RWCS) that collects and treats water from roof surfaces. All other water demands are met by renovated and recycled wastewater, which is obtained by treating all greywater and blackwater.

Assumed water demands in a 4-person dwelling are listed in Table 4.1. Demands in a new house are based on the assumption that water conserving fixtures are installed; an existing dwelling is assumed to contain traditional fixtures, recognizing that demand could be reduced if these were replaced.

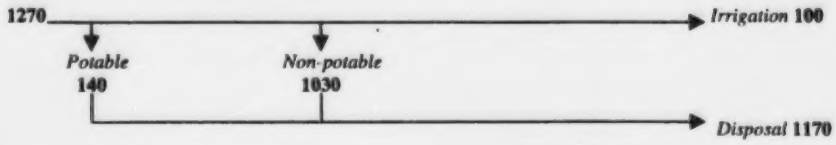
Table 4.1
Water and Wastewater Flows for Innovative Systems

	New Development	Existing Dwelling
Water Demand, L/day		
Potable	135	140
Non-potable	685	1030
Irrigation	100	100
Total	920	1270
Wastewater Flow, L/day		
If irrigation used	35	40
If no irrigation used	135	140

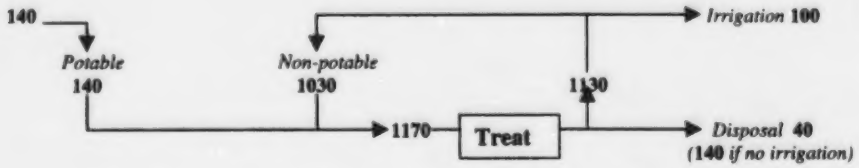
Wastewater flows in Table 4.1 assume that treated wastewater is recycled for non-potable uses, which include all uses except kitchen and bathroom sinks. Recycling and reuse in a new dwelling would reduce the potable water demand—compared with a conventional system—from 920 to 135 L/day; in an existing dwelling without water conservation potable demand and wastewater flow would be reduced from 1270 to 140 L/day.

A. Four persons dwelling with no water conservation

1. Conventional water and wastewater services

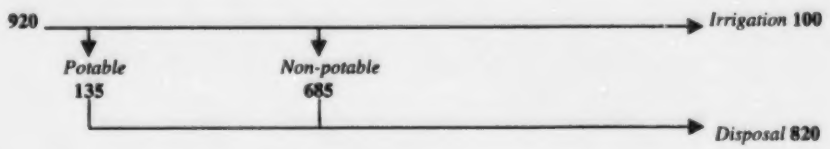


2. Wastewater recycling and reuse



B. Four persons residential dwelling with water conservation

1. Conventional water and wastewater services



2. Wastewater recycling and reuse

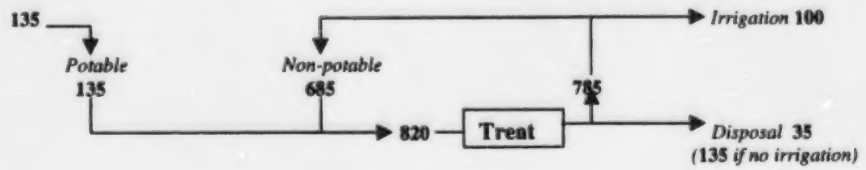


Figure 4.1 Water and Wastewater Flows in Conventional and Innovative Residential Systems, L/day

4.1.2 Rainwater Cistern Systems

Rainwater Cistern Systems (RWCS) were considered as an alternative source to the public system for Millwood and Kingswood, to new wells for Glen Arbour, and for those properties in the Harrietsfield/Millwood area with contaminated wells.

It was recognized that the public systems that supply Millwood and Kingswood provide fire hydrants, which would not be provided by a RWCS. For those systems, the possibility of a public water supply and a Healthy House system for wastewater was also considered. Fire protection is discussed in Section 7.5.4.

A RWCS in Nova Scotia would be assumed to include, in addition to a collection system consisting of conventional gutters and downspouts, a concrete cistern, pump, and ultraviolet disinfection (which is recommended but not required by Nova Scotia Guidelines (10)). The Healthy House, which collects rainwater from roof and yard surfaces in downtown Toronto, includes more complete treatment based on double sand filtration.

It is assumed that the size of an average roof collection area in a new development is 140 m^2. The WATERSAVE program (2), developed by CWRS for CMHC, incorporates a RWCS design program that determines the percentage of days in which a system can meet a specified demand, based on size of the catchment area, cistern size, and local rainfall statistics. A RWCS designed to meet a demand of 140 L/day 100% of the time, based on a collection area of 140 m^2 and rainfall at Halifax, requires a cistern capacity of about 4.5 m^3.

4.1.3 Wastewater Reclamation and Disposal System

Wastewater treatment—using the technology, based on the Healthy House, that is being installed in 10 homes in Yellowknife—includes a specially designed septic tank, followed by a biofilter, sand filtration, and ozonation. It is assumed that a new septic tank will be included for both new and remedial systems, because it is a part of the treatment system, provides better treatment, and is watertight.

Depending on whether or not water conserving fixtures are used, the amount of recycled wastewater will average 685 or 1030 L/day, to serve non-potable uses, and up to 100 L/day for outdoor uses. Depending on the amount of outdoor use, the amount of treated wastewater discharged to the disposal bed will be 40 to 140 L/day.

It should be noted that because this water will be treated to meet health standards for non-potable household uses, it could be discharged to a ditch or storm sewer, particularly in the case of remedial systems, where in Nova Scotia sloping sand filter effluent is now allowed to discharge to a ditch.

The area of the disposal bed will be based on a flow of 140 L/day, and a loading rate of 16 L/day/ m^2. The loading rate is based on the discharge of treated wastewater to a clay, sandy clay, or silty clay.

The Nova Scotia on-site guidelines (8) use a maximum loading rate of 32 L/day/m^2 where a 7.6 cm sand layer is provided below the gravel in the bed to provide a location for growth of the biomat.

Where the sand is not provided, and the biomat grows in the native soil, loading rates are reduced, particularly in tight soils. The maximum rate for a silty clay is 10 L/day/m^2. Tyler (11) proposed a rate of 8 L/day/ m^2 for clay, sandy clay, or silty clay when loaded with septic tank effluent, and 20 L/day/ m^2 when loaded with filtered effluent. The bed used in the Toronto Healthy House is based on a loading rate of 12 L/day/ m^2 .

The rate of 20 L/day/ m^2 proposed by Tyler has been assumed here. Based on this rate, and a loading of 140 L/day, the area of the disposal bed would be 7 m^2, which has been rounded up to 10 m^2. The bed is assumed to be based on a standard C1 system as specified in the Nova Scotia guidelines, except that the sand layer will be redundant because no biomat is expected to form.

4.2 System Costs

Table 4.2 lists estimated costs for the THH systems discussed here.

Table 4.2
Estimated Costs of Components of Innovative Systems

Item	Capital		Annual O&M
	New	Existing	
Rainwater Cistern System	$2,000	$2,000	
Wastewater Renovation System	$10,500	$11,000	
Wastewater Disposal Bed	$900	$900	
	$ 13,400	$13,900	$350

The estimated cost of the RWCS—based on CWRS experience with these systems in Nova Scotia—assumes a 4.5 m^3 cistern, plus a pump, ultra-violet generator, and any additional plumbing that might not be part of a standard household system.

The cost of the wastewater renovation and recycling system is based on demonstration systems recently installed in Yellowknife, assuming that the units will be in commercial production (12). The estimate includes the septic tank, other treatment units, pumps and controls, and plumbing modifications needed to recycle renovated wastewater to non-potable fixtures. Additional cost has been allowed for plumbing and other modifications in an existing dwelling.

5. COMPARISONS OF CONVENTIONAL AND INNOVATIVE SYSTEMS

5.1 Introduction

This section compares costs of conventional and innovative systems for the five case study situations.

5.2 Costs

Cost comparisons, shown in Table 5.1, are based on information provided in Sections 3 and 4.

Table 5.1
Life Cycle Costs of Servicing Alternatives (1)

Scenario	Capital Cost	Annual O&M	Present Worth (2)
Millwood			
New municipal services	$17863	$514	$46078
Healthy House system			
Complete, no fire hydrants (3)	$19200	$350	$46152
Sewage only, fire hydrants (4)	$21072	$567	$53700
Kingswood			
Municipal water, on-site sewer	$21847	$361	$54444
Healthy House system			
Complete, no fire hydrants	$18400	$350	$44472
Sewage only, fire hydrants	$26497	$587	$65425
Glen Arbour			
New on-site Water and Sewer	$13500	$161	$35398
Healthy House – complete system	$18400	$350	$44472
Harrietsfield/Williamswood			
(a) Replace Water and Sewer			
Replace on-site and well (5)	$11256	$161	$30870
Replace on-site and well (6)	$8518	$161	$25120
Cluster system and well (8)	$18629	$146	$55911
Healthy House – complete system	$13900	$350	$35022
(b) Replace sewer only			
Replace on-site	$4690	$161	$17081
Cluster system	$14800	$89	$46922
Healthy House – wastewater only	$11900	$407	$31772
Pomquet			
Central sewer system	$20000	$314	$47230
Healthy House – wastewater only	$11900	$407	$31772

(1) Cost per lot
(2) Based on 150 yrs @ 6 percent
(3) The complete Healthy House system, no public water supply, extra stormwater cost
(4) Healthy House wastewater, public water, extra stormwater cost
(5) Uranium contamination of wells
(6) Bacterial contamination of wells

Cost comparisons between systems are based on the present worth of capital and O&M costs. Assumed life expectancy is 30 years for an average on-site disposal system, and 50 years for all other public and private systems. Each system is assumed to be replaced, or repaired at the same cost, at these intervals, and annual operating costs incurred annually, for 150 years (the shortest interval that provides a common basis of comparison for both systems. Future construction and O&M costs have been updated using the average ENR index (5) discussed in Section 3.1.

Capital and O&M costs for conventional systems in Table 5.1 are taken directly from Tables 3.1 to 3.5. Costs for innovative systems require further explanation:

- If no other public services are required in Millwood, the cost of stormwater piping will be increased because a shared trench will not be possible.
- The water distribution systems in Millwood and Kingswood are designed to deliver fire flows. If domestic demand was eliminated, pipe sizes would not be reduced, and costs would be reduced only by the elimination of building services. Cost comparisons therefore consider Millwood and Kingswood with and without fire protection by municipal hydrants. In the former case, the most favourable situation has been assumed, in which the public system would also provide the domestic supply and a service connection would be required, but reduced demand might reduce the capital and operating cost of the public system.

5.3 Discussion

No attempt has been made here to allocate cost, in terms of responsibility for initial costs (municipality or senior governments, developers, property owners), or in terms of cost recovery (e.g., taxes, water rates, lot purchase price).

The cost comparisons above indicate that the innovative Healthy House technologies considered here might be competitive or less costly in the following situations:

- in Millwood or Kingswood if fire protection by municipal hydrants was not required
- Harrietsfield-Williamswood as an option to a cluster system
- in Pomquet as an option to a remedial central system.

The Healthy House technologies would not be cost-competitive in these situations where:

- fire protection provided by a public distribution system is required
- it is possible to install or replace on-site wells and septic tank systems with conventional on-site systems.

Conclusions based on the values in Table 4.1 would be the same based on 1998 costs, or on the assumptions made in the present worth calculation.

If the cost of the Healthy House technologies is reduced as a result of market demand, some of these conclusions might be altered.

There are a variety of other situations, not recognized in the scenarios represented here, where the Healthy House technologies would be cost-effective. These are discussed further in Section 6.

Cost comparisons in this section do not consider:

- the value of space in a building that is added for, or pre-empted by, a treatment and storage system; the Healthy House system, as installed in the basement of houses in Yellowknife, occupies about 8 m^2.
- the potential reduction in the cost of land for a lot, if the lot size can be reduced because on-site sewage constraints do not apply (see Section 7.5.3).

The cost comparisons in this section do not recognize a variety of other non-cost issues, considered in Section 7, that could ultimately determine the acceptance and use of the innovative technologies considered here.

6. POTENTIONAL APPLICATIONS OF INNOVATIVE TECHNOLOGIES

The preceding sections of this report have identified specific situations where the technologies considered here might result in less costly solutions to water and wastewater servicing in residential single family development:

- in an urban or suburban subdivision if fire protection is not required
- in a non-urban area as an alternative to a cluster system
- in a non-urban area as an alternative to a remedial central system.

These situations are clearly not limited to Nova Scotia or Atlantic Canada.

An infrastructure planning situation documented in (3)—which exists in municipalities across the country but was not represented by the case studies in this report—is that of developments in areas where the capacity of existing water and wastewater infrastructure has reached or is approaching its limit. In these situations, municipalities are faced with the options of: limiting development; investment in expensive new water source, treatment and transmission systems and/or trunk sewers and treatment systems; or on-site services, with implications that are discussed in Section 7.5.3. The alternative technologies discussed in this report offer another potential option in these situations.

Two recent reports prepared by CWRS for CMHC describe Canadian applications of innovative technologies that have been used, or have the potential for use, for residential systems (3) (4). They include both demonstration systems and actual applications, at the scale of single family and multiple unit buildings:

- the Toronto Healthy House (THH), a duplex dwelling in downtown Toronto, located on a street with no municipal water and wastewater, where it would have cost about $155,000 to provide these services;
- areas of Yellowknife, NWT, currently served by trucked water and wastewater at an annual cost of $4,300 per dwelling, where the THH technology is being demonstrated for wastewater service in 10 dwellings;
- native communities in northern Canada, where the THH technology will be demonstrated;
- an apartment building in Vancouver, B.C., where the THH technology will be demonstrated;
- an apartment building in Ottawa, Ont., where a greywater recycling system is being developed for toilet flushing;
- a small municipal building in Sooke, B.C., on a site without municipal sewer service and too small for a conventional on-site system, where all wastewater is recycled for toilet flushing;
- houses, lighthouses, and small commercial buildings in Nova Scotia where rainwater cistern systems (RWCS) are being used in locations where public supplies are not available (at all, or at reasonable cost), and wells are not an option or are contaminated from natural or man-made sources.

A report prepared by CWRS for the Intergovernmental Committee on Urban and Regional Research considered the implications of water conservation measures for Canadian municipal utilities (13).

Figure 4.1 of this report illustrates the impacts of water conservation on both water demand and wastewater production in a single family home.

Generally, the technologies considered here have potential application in any situation where water supply from public supplies or groundwater, or wastewater disposal capacity via a public or on-site system, is limited, not available, or expensive. They can be useful because

- rainwater cistern systems (RWCS) provide an alternative water source to a public system or private well
- wastewater recycling and reuse improve wastewater quality and expand disposal options
- wastewater recycling and reuse, and water conservation measures, reduce water demand and wastewater production, and thereby widen the application of RWCS and on-site disposal systems, or reduce demands on public systems.

The following section of this report identifies and discusses issues that must be addressed when use of these systems is considered.

7. ISSUES

7.1 Introduction

Table 7.1 summarizes issues other than costs—technological, management, regulatory, public and political—that may have to be addressed when use of the systems described here is considered. These issues, identified in the course of this and other projects conducted for CMHC (e.g. (3)), are discussed in the remainder of this section. This discussion is limited to systems for on-site wastewater recycling and reuse: rainwater cistern systems are generally based on available technologies, can be managed by the building occupant, and can be guided or regulated by provisions such as those contained in the Nova Scotia guidelines (8).

Table 7.1
Issues

1. TECHNOLOGICAL
• Ability to meet health and environmental quality criteria
• Reliability – risk
• Reliability – level of service
• Operation and maintenance requirements
• Monitoring and control
2. MANAGMENT
• Responsibility – public or owner
• Institutional options – public or private
3. REGULATORY
• Responsibility– federal, provincial, municipal
• Requirements – performance or specifications – quality criteria – conditions for use
• Instruments – water quality criteria, health codes, building codes
4. PUBLIC AND POLITICAL
• Acceptance – health – aesthetic: real or perceived – level of service vs "flush and forget" – re-sale
• Land Use and Infrastructure Planning
• Fire Protection

7.2 Technological Issues

Design constraints for any system intended for recycling or reuse of wastewater in a residential system should include:

(1) Renovated wastewater must meet health and environmental quality criteria specified by responsible government agencies.
(2) System malfunctions must not threaten individual health or the environment (e.g. renovated water quality deteriorates on system shutdown).
(3) System malfunctions should be minimized by designs that emphasize reliability.
(4) Operation and maintenance should be facilitated by system design (e.g. on-site systems should be provided with sensors and alarms, and be easily accessible).

(5) Essential water quality parameters (e.g. turbidity) must be continuously or periodically monitored, and provision be included for manual sampling for parameters that cannot be measured on-line (e.g. micro-organisms).
(6) Remote monitoring and control should be important design considerations.

"An Application Guideline for Water Reuse Systems" (14) discusses technical issues that should be addressed in planning and design of reuse systems, including water use, wastewater quality, key water quality parameters, renovated wastewater quality for various uses, design flow, process reliability and its relationship to multiple treatment units, distribution system safety, and system expandability and system testing. The report also provides a checklist of issues to be addressed in engineering studies, plans, and specifications.

Most of these issues are being addressed in the design and continuing development of systems for on-site recycling and reuse, including the THH and systems based on that technology, and other systems that are described in reference (3).

7.3 Management Issues

The complexity of systems for wastewater recycling and reuse, and the potential consequences of system failure, require a level of understanding, commitment, and capability that it is not reasonable to expect from most householders. These systems should not be installed unless positive provision has been made for their long-term management by persons with the required knowledge and experience.

Management implies monitoring, inspection, maintenance, repair and replacement.

Two possible management models (there may be others) are:
(a) A Wastewater Management District (WWMD) may be established by a municipal unit to manage private systems and recover associated costs from property owners. WWMDs are enabled by provincial legislation in Nova Scotia; US examples are listed and discussed in (15).
(b) Legislation or regulations may require a property owner to employ a licensed private firm to manage the system and report periodically to the regulating agency, and impose fines if the owner fails to comply. Requirements of this nature are currently applied to management of sophisticated on-site wastewater treatment systems in some US jurisdictions.

Reference (14) recommends that a system operation and management manual be prepared, and lists information that should be considered in preparing it. The report also lists considerations involved in development of monitoring requirements.

7.4 Regulatory Issues

Legislation, regulations, and criteria that relate to on-site wastewater recycling and re-use might be applied by federal, provincial, or municipal agencies.

Requirements that might be applied could relate to
- limitations on use of renovated wastewater
- water quality criteria for specific uses

- performance requirements and/or specifications related to system design (Section 7.2)
- requirements for system management (Section 7.3).

Regulatory instruments that might be employed include water quality criteria, building and plumbing codes, and on-site sewage regulations. These are commonly a combination of specifications (e.g., for pipe materials, labelling, etc.) and performance requirements (e.g., for treatment facilities).

Reference (14) summarizes water quality testing requirements for the Toronto Healthy House, and those included in Washington State reuse regulations and British Columbia installation guidelines for recycling treatment systems.

A recent report on "Regulatory Barriers to On-site Water Reuse" (16) examines potential or perceived regulatory barriers in federal provincial and territorial jurisdictions. The only restrictions that apply explicitly to wastewater reuse are those that deal with the quality of water applied to agricultural crops. Requirements that can influence the adoption of recycling and reuse systems are:

- the National Plumbing Code and provincial plumbing regulations require that every water system be connected to a potable supply, and prohibit discharge of non-potable water to any fixture where a potable supply is available
- requirements that all wastewater be directed to a sewer or an on-site disposal system.

Officials are generally concerned about health, reliability, and other issues that are identified here. The report concludes "As long as existing regulations are open to some degree of innovation there are no absolute barriers to on-site reuse. There will remain, however, administrative obstacles based on individual attitudes, interpretations, and other factors which in themselves can pose significant barriers. The solution may be to distill the successful experiences into a Code of Practice and case studies to provide guidance and confidence to decision makers, facing approval of on-site reuse systems, that practical and safe systems do exist." (16)

A proposed amendment to the British Columbia Plumbing Code (included as an appendix in (13)) deals with recycled wastewater systems under the following headings: design; installation; testing; prohibition of connections to potable water systems; materials; identification of pipes, fittings, and fixtures; location of pipes and outlets; backflow prevention; and recycled wastewater valves that can only be operated by authorized personnel. References cited are an American Waterworks Association Manual (17), and a National Sanitation Foundation standard (18).

Draft British Columbia municipal sewage regulations (19) deal with standards for effluent reuse, and include, for various categories of unrestricted and restricted public access: treatment, effluent quality, and monitoring requirements.

Reference (14), prepared to assist persons seeking approval, and regulatory agencies considering approval, of water reuse systems, provides an example application form with instructions on how to complete it.

"Regulatory Obstacles to Innovative Housing" (20) provides a useful overview of regulatory obstacles to acceptance of a variety of innovations in residential buildings, including recycling, reuse and disposal systems. Case studies and other examples are provided. The report concludes that building codes and regulations do not always inhibit innovation; it recommends that municipal regulators

consider policies and by-laws that recognize, encourage, and reward use of innovative water and wastewater systems that result in more effective land use, or in no net loss of capacity in a municipal water supply or wastewater system.

7.5 Public and Political Issues

7.5.1 Introduction

Even if systems for recycling and reuse are cost-effective, and if health and environmental concerns are addressed by management and regulatory requirements, acceptance of these systems may be limited by other real or perceived concerns. And adoption of these systems raises land use and infrastructure planning issues that must be addressed.

7.5.2 Acceptance

Following are some of the issues that may concern potential owners of these systems, may affect their willingness to purchase properties that include these systems, or may influence political decisions about accepting them as alternatives to conventional systems:

- notwithstanding regulatory approval, concern about the health implications of using reclaimed wastewater
- aesthetic aversion to use of reclaimed wastewater, instead of potable water, for non-potable uses
- reluctance to accept any responsibility for system operation and management beyond that required when municipals services are available (e.g. even if management is provided by a public or private agency, an owner may have to respond to an alarm, or suffer the inconvenience associated with a temporary system shutdown)
- limitations on what can be discharged to a wastewater recycling or reuse system
- concern about the resale value of a property that is serviced by an unconventional system.

These concerns may be addressed as more experience is gained about the performance and reliability of these systems, and related information is made available to prospective owners.

7.5.3 Land Use and Infrastructure Planning

This section is based primarily on discussions with the Advisory Committee for this project, and with Halifax Regional Municipality planning staff, local consultants, and representatives of the developers of three of the case study projects considered in Sections 3 to 5.

The planning concerns considered here relate to housing developments beyond the limits of existing sewer infrastructure, which have been or probably will be served by on-site wastewater systems. These developments may be within or outside of the area in which municipal water is available, e.g., Kingswood is within, and Glen Arbour is beyond, the serviced boundary of the Halifax Regional Water Commission.

A consequence of on-site servicing is a requirement for larger lots. Lot prices depend on location, services, and lot size. Lot prices range from:

- $20,000 to $30,000 for a fully serviced lot in Millwood, with lot sizes 400 to 600 m^2

- about $50,000 for a fully serviced lot of the same size in Bedford, the nearest urban centre in the Halifax Regional Municipality
- about $30,000 for a 5,000 to 6000 m^2 lot with municipal water service in Kingswood
- $50,000 to $110,000 for a 5,000 to 6,000 m^2 unserviced prestige lot with golf privileges in Glen Arbour.

Lot sizes may be dictated by zoning or other planning requirements, by on-site wastewater regulations, or by market conditions.

If adoption of the Healthy House technology removed limitations on lot sizes, lots in Kingswood and Glen Arbour might be as small as the 500 m^2 lots in Millwood, depending on planning restrictions. But increased lot size is a major reason, in addition to price, why properties in these areas are preferred to those in Millwood or Bedford. Developers indicate, however, that in non-urban developments a lot size larger than about 3,000 m^2 will not necessarily bring a higher price, which suggests that adoption of the Healthy House technology might reduce average lot sizes in these areas by half. But they also indicate that the larger lot sizes in Kingswood and Glen Arbour offer an important marketing advantage, i.e., adoption of the Healthy House technology would not necessarily reduce lot sizes, costs to a purchaser, or urban sprawl.

Municipal planners are concerned about costs and consequences that are associated with urban sprawl. These include, in addition to the costs of water distribution that have been discussed above:

- road costs: capital, and operation and maintenance
- public transit and transportation costs for school and recreation
- environmental effects: loss of wetlands, forests, and effects on natural streams
- increased refuse collection costs
- increased vehicle emissions.

They are also concerned that a larger lot does not, per se, provide an enhanced life style, when the costs and inconvenience listed above, and reduced access to urban amenities, are considered.

A recent report prepared by the Halifax Regional Municipality (21) drew attention to the effects of relatively large, non-contiguous, low-density residential development in areas like Kingswood and Glen Arbour. In addition to the concerns above, it refers to the possible future high costs to the municipality if individual on-site systems are not maintained and central services must be extended to these areas.

The report suggests that consideration be given to clustered developments in which groups of smaller lots are served by a single septic tank and sub-surface disposal system. Specific advantages cited are: preservation of the remaining land area for forestry, farming, or open space; minimized length of roads; and reduced costs if central services are extended in the future. The report recognizes that a wastewater management system must be in place if this option is to be adopted. Reference (22) includes a discussion of environmental implications of large-lot non-urban developments based on use of private sewage facilities.

The Healthy House technology could offer a wastewater treatment alternative in this situation, by permitting small lots without the need for a collection system. A wastewater management system

would still be required. Cost considerations would include the presence or absence of rock in trench excavation for a collection system, and soil conditions for a conventional subsurface disposal system.

The forgoing discussion assumes that land use controls are in place to assure that—if smaller lot sizes are enabled by a cluster system or the Healthy House technology—open spaces are preserved, and that removal of lot size limitations imposed by conventional on-site systems does not result in unwanted dense development in non-urban areas.

7.5.4 Fire Protection

Fire protection must be considered in areas where a municipal water system is not available. In the recently-amalgamated Halifax Regional Municipality (HRM), fire protection is managed by the Director of Operations. "Core area" fire brigades, comprised of previous municipal systems of the communities of Halifax, Dartmouth, and Bedford, and several previously volunteer systems that are immediately adjacent to these systems, are directly under his control and funded by HRM through general revenues. The remainder of the HRM continues to be protected through locally funded and managed volunteer fire departments. These departments report to the HRM Director, and his office provides liaison and coordination. 911 emergency service is available throughout the HRM.

Volunteer departments generally serve areas where public water mains and hydrants are not available. Some volunteer departments, such as the one that serves both Kingswood and Glen Arbour, serve areas with and without public mains and hydrants.

Where public water mains and hydrants are not available, water can be brought to a fire site from a local lake, pond, or stream by

- a high volume hose and a portable pump, and/or
- a tanker truck that shuttles between the source and the fire site, discharging its load to a "port-a-tank" that feeds a pumper truck.

The former alternative is less costly, but is dependant on larger numbers of volunteer firefighters.

Dry hydrants are installed to facilitate easy and rapid access to local water sources. They include a pipe that extends below the surface of a water source, and is carried to a convenient location where a tanker can connect.

Alternative fire protection systems are described and discussed in references (23) and (24).

An indication of relative effectiveness of hydrant-based protection vs trucked water may be fire insurance rates:

- The Insurers Advisory Organization describes 5 "Dwelling Protection Classes", ranging from fully protected by a full-time fire department and a hydrant system to unprotected; individual insurers may base their rates on all 5 classes, or as few as 2 classes.
- The largest Nova Scotia insurer uses 3 classes. Rates are governed by both risk and market conditions. A typical annual insurance premium for a $100,000 residence would be:
  - $386 for a fully protected dwelling
  - $750 for an unprotected dwelling.

Their most common product is for a semi-protected dwelling, for which the rate would fall between the two values above, depending on the capabilities and resources of the local volunteer department.

8. STRATEGIES AND ACTIONS

8.1 Conclusions

(1) It is clear from Section 5 that the THH technology can be cost-competitive with conventional technologies in a variety of situations.

(2) Section 6 and reference (3) describe successful examples of other technologies and servicing alternatives that involve recycling or reuse of renovated wastewater.

(3) It is also clear from Section 7 that successful implementation of any of these technologies requires that the issues identified in that section be recognized and addressed.

8.2 Recommendations

Strategies and actions that can take advantage of opportunities, and address problems and issues, that have been described in the earlier sections of this report, include:

(1) Technologies for wastewater renovation will continue to develop in response to regulatory and market demands. Particular emphasis should be placed on development and application of technologies for monitoring and control of these systems.

(2) Management systems—public or publicly controlled—will have to be devised or adapted to insure that on-site systems for wastewater renovation are operated and maintained at a level that will insure reliability of service and protection of individual health and the environment.

(3) Regulatory obstacles to adoption of these systems should be addressed by additions or changes to codes, standards, and regulations. These changes should insure that only appropriately designed and managed systems are installed. Bad examples or system failures—in terms of health or environmental effects, costs, or failure to meet owner expectations—will influence future decisions about acceptance of these systems.

(4) Information in this report and related references—about the capabilities and advantages of these systems, and about relevant issues that must be addressed—should be communicated to planners, designers, developers, regulators, politicians, and prospective property owners.

It is essential that real or perceived concerns of the public, politicians, and regulators be recognized and addressed.

Possible vehicles for this information are CMHC reports, conference presentations, and professional publications. Availability of this information can be announced in newsletters and journals of national and provincial organizations. Public information might be provided through press releases, and through provincial and municipal agencies and community groups.

(5) Land use and infrastructure planning implications of the adoption of these technologies should be recognized and addressed. These include
   - high costs of infrastructure and municipal services, and loss of land for agriculture, wetlands, and other uses, in areas where large lot sizes are required for on-site sub-surface systems
   - innovative technologies could remove or reduce limitations on lot areas
   - concerns that if density controls imposed by on-site systems are removed and not replaced by land-use controls, suburban areas may be occupied by small-lot urban developments, again with loss of land for agriculture, wetlands, and other uses
   - recognition that market forces may demand larger lots—although not necessarily as large as those required by on-site services—in suburban areas
   - cluster systems, served by conventional or innovative systems, provide a planning and management alternative that can preserve open spaces in suburban and rural areas.

(6) Continued research and demonstration are required:
   - Improved technology should reduce cost and provide better monitoring and controls.
   - It is important to provide examples to illustrate how these systems can be effectively regulated and managed.
   - This project was limited to a comparison between the Toronto Healthy House technology—with and without a rainwater cistern system—and conventional servicing alternatives. Other technologies have been used or proposed that limit use of renovated wastewater to toilet flushing or irrigation; use of these technologies—although they may result in smaller reductions in water use and wastewater production—may be more acceptable than systems that use renovated wastewater for other purposes.

(7) It should be recognized that options to conventional servicing are not limited to on-site recycling or reuse:
   - Public systems in which wastewater is recycled and reused are summarized in reference (3).
   - Cluster systems in non-urban areas (22) offer both an alternative technology and an example for decentralized wastewater management.

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